PNEUMATO-THERAPY.

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PNEUMATO-THERAPY.

BY pneumato-therapy is meant the utilization in the treatment of disease, of those modifications in the performance of the functions of organic life, which are brought about by modifications of the physical condition of the atmosphere in which the patient is immersed, or of the air he breathes, or of both.

The atmosphere may be modified for therapeutic purposes in respect to its density, its temperature, or its humidity. It is of changes of density only—that is, of pressure phenomena—that I desire to speak this evening.

Changes of atmospheric pressure are used in medicine by either of two methods, which have been respectively termed, the absolute method and the differential method.

An absolute change of atmospheric pressure, affects both and equally the respired and the surrounding atmosphere. A differential change affects one of these factors only, or both unequally. Differentiation may be made to (directly) affect inspiration only, or expiration only; or it may be made to affect both phases of respiration, equally or unequally, in the same or in opposing directions.

While it is true, that patients may by change of residence to a more or a less elevated region, be subjected to absolute change in atmospheric pressure, yet this is, after all, but one of the factors in climato-therapy, and a brief allu-

sion to the fact is all that properly falls within the scope of the present paper.

The absolute method in pneumato-therapy is applied by means of apparatus termed pneumatic chambers ; a number of which have been constructed and are in use at different points in Continental Europe, but I am not aware of any establishment of the kind in English-speaking countries. The first of these was made, after designs by Tabarie, in 1838. The literature of the subject, however, is much older,* Tabarie having made his first communication to the Academy of Sciences at Paris in 1832, and Jounod having presented his first paper in 1835 ; while even in the eighteenth century, the attention of naturalists had been directed to the effects of condensed air on animal and vegetable life. Tabarie's cabinet could be used only with compressed air. G. Lange modified the apparatus so that rarefied air might also be employed, and so that expiration, if so desired, might be made directly into the outer atmosphere. In this latter respect, we find the first attempt at differentiation. It was in Lange's cabinet that Von Vivenot prosecuted his valuable and laborious researches. Von Liebig designed for the Mack Brothers at Reichenhall a pneumatic chamber said to be the best in existence, while that of Simonoff at St. Petersburg, consisting of a stone

* For historical and bibliographical details, see J. Solis-Cohen, "Inhalation: its Therapeutics and Practice," second edition, Philadelphia, 1876; Oertel, "Handbuch der Respiratorischen Therapie," Leipzig, 1882. English translation by J. Burney Yeo, London, 1885.

chamber and two iron ones, is said to be the most elegant in its appointments. The patient, or a number of patients, having entered one of these appliances, the contained air is then gradually condensed or rarefied by means of a steam-pump ; the pressure being gradually restored to the normal after a sitting of from half an hour to two hours or longer. Special appliances secure proper ventilation, and permit regulation of pressure, of temperature, etc. These chambers are very costly, and their use necessarily restricted to certain resorts. Hence, for a long while, various attempts have been made to construct cheaper and portable apparatus. The portable apparatus utilize the differential method,—that is to say, the air within the lungs is rendered different in pressure from the surrounding atmosphere.

Changes of intra-thoracic air-pressure can of course be obtained without any apparatus whatever. Thus, if, while nostrils and mouth are closed, forced expansion of the chest be made (Müller's experiment), the air within the lungs will be rarefied ; and conversely, if, after a full inspiration, the glottis, or the mouth and nostrils, be closed, and an effort made to contract the chest (Valsalva's experiment), assisted, perhaps, by manual compression (Weber's experiment), the intra-pulmonary air will be condensed. A less degree of condensation may be caused by expiring through but partially-closed lips ; and a simple contrivance based upon this principle—a narrow tube, with a ball-valve to resist expiration —produces the same effects as expiration into compressed air. It is obvious, however, that

the effect of rarefaction can thus be obtained only during a prolongation of the inspiratory phase of the respiratory act, while compression can be brought about only by a baffled or impeded expiration. The respiratory rhythm is completely deranged, the mechanical force employed and developed remains an unknown and variable quantity, while the disturbance of circulation is usually out of all proportion to the therapeutic value of the expedients.

Resort to apparatus for furnishing a supply of condensed or rarefied air is therefore preferable. Simple matter as the construction of such apparatus should seem to be, it was not until 1870 that any practical device at all fulfilling the necessary conditions was made; and not until 1874 that a reliable apparatus was presented to the profession. To Hauke, of Vienna, belongs the credit of having made the first approach to a suitable instrument; and to Waldenburg, of Berlin, is due the honor of having constructed an apparatus which has served as the model of the best of subsequent ones, and of having placed pneumato-therapy upon a firm scientific basis, by patient and accurate physiological and clinical studies.*

In the arrangement of apparatus for the therapeutic use of compressed and rarefied air, two desiderata must be secured with mathematical precision, — 1. The pressure must be a known and controllable quantity; 2. It must be constant, or varied only at will. The physical principles involved, are identical

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* "Die Pneumatische Behandlung der Respirations und Circulations Krankheiten," Berlin, 1875.

with those involved in a study of the physiological effects of pneumato-therapy; depending upon the properties of the gaseous state of matter, the tendency of matter in whatever state to move in the direction of least resistance, and the fact that the effect of terrestrial gravity upon the atmosphere, is to subject everything upon the surface of the earth to a continuous pressure, which, measured at sea-level, is represented by the weight of a column of mercury 760 mm. (29.9 inches) high,—*i.e.*, in round numbers, fifteen pounds to the square inch.

Two classes of apparatus have been constructed for the utilization of differential pressure. In the one, the air is condensed or rarefied in a receptacle from which the patient inspires, or into which he expires; in the other, the patient is placed within a contrivance in which the air surrounding his body, or a portion of his body, may be condensed or rarefied, while he breathes the ordinary atmosphere. Instruments of both classes were first constructed by Hauke.

We will consider first the most useful class, that in which the patient remains outside the apparatus.

Pressure or rarefaction may be obtained on one of three plans, which may be termed the water-level plan, the gasometer plan, and the bellows plan. The water-level plan depends upon the fact that change of water-level, without entrance or exit of air, in a vessel containing both air and water, will alter the density of the air. This was the principle first adopted by Hauke, and subsequently by Stoerk. Apparatus constructed on this plan

simply, are not reliable, and are inconstant. The bellows plan depends upon the fact that a receptacle, with extensible and collapsible walls, may be made by expansion of the cavity to rarefy the contained air, and by contraction to condense it. The lungs work in this manner. The best apparatus for pneumatotherapy constructed on this principle is that of Biedert; one of the simplest and cheapest that of B. Fraenkel. While they are said to have answered admirably, they evidently can easily become fouled if used for expiration, and the pressure does not remain constant. Biedert's is also troublesome to manage. The principle is simple, however, and means for its employment readily available. Thus, J. Solis-Cohen, in 1866,* used a kitchen bellows to administer inspirations of condensed air, and the same writer in 1880† highly recommended a simple expedient to secure compression, suggested by Dr. W. Y. Gadberry, of Yazoo City, Mississippi,—namely, the employment, after deep inspiration, of an ordinary rubber hand-ball to force an additional quantity of air into the lungs,—as being more useful than drugs in promoting expectoration.

The gasometer plan depends upon the fact that if a vessel open at bottom, and with an opening at top to admit air, which may be closed when desired,—being suspended over water in another vessel, freely communicating with the outer air,—be raised out of the water by a force sufficient to overcome

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* Op. cit., p. 55.

† Trans. Med. Soc. of Penna., Phila., 1880.

gravity and atmospheric pressure, the air will rush into its interior; that if the cylinder be then closed, the contained air may be rarefied or condensed by adding or subtracting gravity, or its equivalent, to or from atmospheric pressure; and that the positive or negative pressure thus obtained is independent of the volume of air within the air-chamber, which will rise or fall within the water accordingly. Thus we have a ready means of obtaining any desired pressure and of maintaining it, whether we withdraw air by inspiration, or add air by expiration. This is the principle upon which Waldenburg's apparatus is constructed, and upon which depend the modifications of Schnitzler, Weil, Tobold, Finkler and Kochs, and others, all admirable instruments and thoroughly reliable. The best of these are expensive. The minor objections to all instruments of this class are that they are more or less cumbersome, are troublesome to manage, and are not continuously acting, the capacity of the cylinder being of course limited.

This latter objection has been overcome in various ways. Some have so combined two cylinders that one rises while the other falls, and *vice versa*, permitting the patient to use one or the other alternately, with but slight interruption to the process. Geigel and Mayr, whose instrument Oertel commends above all others, have combined a water-level instrument (water-engine bellows) with a gasometer-bell; a series of revolving buckets taking up or discharging a certain quantity of water to compress or rarefy the contained air, which passes into the bell. This instru-

ment is very costly. The continuous action, which is its great merit, can be secured in a much simpler and cheaper manner, by combining a foot-bellows, such as is used by dentists, with a Waldenburg or other gasometer. This is practically the plan of the instrument which, with the assistance of Mr. Chas. Richardson, I devised in 1883, and which I have already described and exhibited to this society. Originally intended, only to furnish to patients a cheap and safe instrument for home use with compressed air, I have found it capable of modification in other directions; so that when Mr. Richardson has concluded some experiments which he has kindly undertaken to test the feasibility of plans submitted to him, I hope to be able to present to the society an improved instrument, but slightly advanced in cost, which may be used for all the purposes to which the more expensive instruments are applied. Scales and gauges for exact research, may of course be attached to this, as to any other apparatus. To all of the forms of apparatus mentioned, except the simple accordion of Fraenkel, attachments may be added for warming, chilling, drying, moistening, or medicating* the air. Whatever plan be adopted, separate instruments should be used for expiration and inspiration; or two cylinders or bells may be combined in one

* My own usual practice is to pass the air through a Wolff bottle containing a volatile medicament, suspended or dissolved in water, or floating upon the surface of the water. Creasote, terebene, thymol, iodine, benzoin, and similar substances may be thus employed. There are many other ways of medicating the respired air, but this subject is not properly within present limits.

instrument, as in the "double ventilators" of Waldenburg, Weil, Schnitzler, and Geigel and Mayr. Each patient should have his own mask or mouth-piece.

In order to obtain condensation or rarefaction of the atmosphere surrounding the chest, or the body, of patients unable, or, as in the case of children, unwilling, to undergo treatment by methods requiring their more or less active co-operation, Hauke has devised two forms of apparatus. In one, the chest only is surrounded by an air-tight cuirass, the air between which and the thoracic walls is either condensed or rarefied, the patient respiring the ordinary atmosphere. In the other form, the trunk and limbs enter the apparatus, the face alone being free. A very elegant but more elaborate and expensive means of arriving at the same result, is the pneumatic cabinet devised by Mr. Ketchum, of Brooklyn, and introduced to the profession by Dr. H. F. Williams of that city. The patient sits in an air-tight cabinet, the air about him being condensed or rarefied, while he respires the ordinary air, which is conducted to his mouth from the outside, by tubing. The respired air is charged with sprays of certain substances.

Were it not for the undemonstrable and misleading claims put forth by the proprietors of this patented instrument, and the questionable propriety of the methods by which it has been placed upon the market, I might pass it with this simple allusion. But since certain claims of historical novelty have misled even so accurate a student as my friend Dr. Platt, of Lakewood, who has completely disproved

claims of scientific novelty and unscientific mystery,* I cannot complete this portion of the present article without a plain-spoken denial of these claims. That the instrument is not new in mechanical principle—whatever novelty and merits it may have in mechanical details, from which I have no desire to detract—is proved by the simple reference to the pneumatic chamber of Lange, and the pneumatic cuirass and pneumatic tub of Hauke. That it is not new in therapeutic principle goes almost without saying; for since differentiation of intra-thoracic from extra-thoracic pressure is the sole object, of what moment can it be, whether this differentiation be obtained by raising the one, or by lowering the other? Until those who claim superior virtues for the pneumatic cabinet can prove that the difference between 29 and 30 is either greater or less than the difference between 30 and 31, they will scarcely find general acceptance of their proposition.†

That the cabinet offers a convenient and elegant method of applying some of the well-known principles of pneumato-therapy, none can deny. Those who prefer it to other and simpler means of accomplishing the same end, are justly entitled to use and express the preference. I simply wish to place on record a flat denial of the assertions that there is any therapeutic novelty about it; or that anything whatever can be done with it, that cannot be

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* *N. Y. Medical Journal*, Nov. 6 and 13, 1886.

† The questions as to penetration of sprays and vapors are not now under consideration. Dr. Platt's article will elucidate this matter.

done at least equally well, and, in some instances, better, with Waldenburg's, Schnitzler's, or Geigel and Mayr's instrument; or that the results obtained by its use are any better than those obtained for nearly fifty years in Europe, and for at least ten years in America, with the various methods of pneumatotherapy, which I have described this evening.

This will be made clearer as we now pass to the consideration of the mechanical effects of compressed and rarefied air upon circulation and respiration. I say mechanical effects, for these are calculable and measurable with mathematical exactitude. That there must result as well certain other effects, through the nervous system especially, hardly admits of doubt; but the evidence is not perfectly clear and uncontradicted, and the explanation of observed facts is yet involved in obscurity. Not so, however, with the effects due solely to pressure, which follow the same rules as pressure-effects outside the body.*

Let us first review briefly, the well-known mechanism of respiration and of circulation. When by the expansion of the thorax, the contained air is rarefied, the denser outer air tends inward; when the thorax contracts, it compresses the contained air, which tends outward to the now rarer atmosphere. The amount of normal differentiation is small,

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* For physiological data and references, see Landois's "Physiology," translated and edited by Stirling. For the physical principles, consult Ganot's or other standard works on "Physics." For elaborate studies, see Waldenburg's and Oertel's works cited. The latter gives full references to investigations up to the date of publication (1882).

having been estimated, from observations made in cases of wounds of the trachea, at — 1 mm. Hg. during inspiration, and + 2 to 3 mm. Hg. during expiration. Forced inspiration, however, gives a negative pressure averaging 57 mm. Hg., while forced expiration gives a positive pressure averaging 87 mm. Hg.

The average volume of air which enters or leaves the chest during inspiration or expiration, *the tidal air*, is small, having been estimated at twenty cubic inches; but on forced inspiration this can be increased by one hundred and ten cubic inches of *complemental air;* while forced expiration can expel one hundred cubic inches additional, properly termed the *reserve air*, improperly, the *residual air;* leaving still in the chest one hundred cubic inches of *residual air* or *stationary air*. The term *residual air*, as used in this paper, refers to the latter quantity. The object of this movement of air, is to introduce into the blood O, and to remove from it CO_2. This is accomplished in the alveoli; the air of which is consequently continually richer in the latter gas, and poorer in the former, than the air of other portions of the lungs; there being by diffusion a gradual increase of one and diminution of the other, until we reach the trachea and larger bronchi, in which the air most nearly corresponds to the outer atmosphere. At each inspiration there is an absolute as well as a percentage gain of O and percentage loss of CO_2; at each expiration there is an absolute loss of both, without percentage change from the end of inspiration, except as effected by the gaseous movement within the alveoli. This movement is in

part due to the relatively higher tension of O in the alveolar space, and of CO_2 in the blood, the former passing inward, the latter outward. The volume of O which can be absorbed by the blood is the same at all pressures, but as the weight of a given volume increases with its density, the weight of gas absorbed increases with the pressure. The combination of O with the hæmoglobin, and the liberation of CO_2 from the salts of the plasma, depend largely upon the partial pressure of these gases; association being favored by high partial pressure, dissociation by low partial pressure. Now, both tension and partial pressure, while necessarily depending upon actual pressure, also depend directly upon relative volume, other things being equal. Consequently, whatever tends to increase the relative volume and actual pressure of O in the alveoli, within certain limits, facilitates both its passage into the blood and its association with the hæmoglobin; and whatever tends to diminish the relative volume of CO_2 in the alveoli, within similar limits, facilitates its dissociation from the salts and its escape from the blood.

Whatever increases pulmonary ventilation —that is, the volume of air taken in and expelled during each act of respiration—manifestly increases the pulmonary supply of O, and diminishes the quantity of CO_2; and pulmonary ventilation will be facilitated in one respect by an increase in the negative pressure of inspiration, and in the other, by an increase in the positive pressure of expiration. The weight of O in any given volume of air, and consequently in any given

volume of O absorbed into the liquid blood, is of course increased directly as the pressure. Any process that would, while increasing the weight of O absorbed, also increase the rapidity and volume of the pulmonary circulation, would thereby bring a greater number of corpuscles into contact with the greater number of atoms of O, and thus cause increased oxidation of hæmoglobin.

The elastic tissue of the lungs has a tendency to collapse, which is opposed by the contained air and by the movements of inspiration; creating a condition of elastic tension. The force thus developed has been estimated at 30 mm. Hg. at the end of inspiration, and at 6 mm. Hg. at the end of expiration, or in the dead subject. The elastic traction of the lungs is a principal factor in dilating the auricles when they relax after systole; and the blood-pressure in the auricles being then less than in the venæ cavæ and the pulmonary veins, the blood flows into the heart. When the ventricles contract, the pressure within the heart becoming greater than that within the pulmonary artery and the aorta, the blood flows into the pulmonic and aortic systems. As the elastic tension is greatest in inspiration, that movement facilitates distention and filling of the auricles; while at the same time the rarefaction of the intra-thoracic atmosphere, likewise favors dilatation of the heart, and the influx of blood into it and into the venæ cavæ. In expiration, the elastic traction ceases to oppose systole, and the compression favors the expulsion of blood from the heart, facilitating likewise the outflow from the aorta and its intra-thoracic branches.

Inspiration thus favors circulation, especially through the pulmonic and venous channels; expiration, through the aorta and its subdivisions. An increase in the pressure of the air respired, beyond the limits of ordinary barometric changes, would increase the inspiratory effects due to traction, but somewhat diminish those due to the negative pressure; it would also slightly increase the expiratory effects of pressure, while introducing an increased opposition due to the heightened tension. Diminution of pressure would, of course, have the opposite effect. There is always a slightly less pressure upon the pulmonary veins than upon the pulmonary capillaries, thus permitting the ready inflow of blood through the pulmonary circulation.

We have assumed in this outline study of the relations between respiration and circulation, that the respired air is of the same density as the surrounding atmosphere, and that at the end of inspiration, and at the end of expiration, the pressure within the thorax becomes the same as that upon the periphery of the body; and this is the normal condition. Obviously, if this condition be altered, the circulation will be correspondingly affected. The blood will tend from the point of high pressure to the point of low pressure, —from the thorax, if the air therein be condensed—towards the thorax, if the contained air be rarefied. In Mueller's experiment, for example, the negative pressure of inspiration is maintained and increased throughout the act. This increases cardiac dilatation; more blood flows into the heart and into the lungs, much less blood is expelled from the left ven-

tricle, so that heart and lungs are engorged and the aortic vessels comparatively empty. The pulse may disappear. The blood-pressure and arterial tension are at first diminished, the arterial tension rising afterwards from vasomotor reaction.

In Valsalva's experiment, there is maintenance and increase of the positive pressure of expiration. The cardiac chambers and thoracic vessels are compressed; no blood can enter the right auricle or venæ cavæ; the blood in the lungs rapidly passes into the left heart, thence into the aorta, and out of the chest. The lungs and heart contain little blood, the peripheral vessels are distended, with at first increase of blood-pressure and of arterial tension, which afterwards falls from vasomotor reaction. Notwithstanding the increased pressure, the pulse may be absent from the same cause,—lack of blood in the heart,—to which the absence of the cardiac sounds is attributed.

By the use of apparatus for inhaling compressed air, the negative pressure of inspiration may be converted, as the act proceeds, into a positive pressure—and conversely by making expiration into rarefied air, positive pressure becomes converted into negative. We have then, at first a heightening, afterwards a reversal, of the normal cardiac-respiratory reactions.

One other feature of the respiratory act remains to be noted. One of the forces which the muscles of inspiration have to overcome, and which assists expiration, is atmospheric pressure upon the thoracic walls. The muscular labor of inspiration may be diminished

either by invoking the assistance of another force, or by diminishing the resistance to be overcome. The first method is secured by increasing the density of the inspired air over that of the surrounding atmosphere; the second, by diminishing the atmospheric pressure. Reversal of the conditions would impede the act. In a similar manner, expiration may, by pressure differentiation, be facilitated or impeded.

Having thus fully considered the principal conditions of our problem, we can briefly summarize the observed effects of the therapeutic applications of compressed and rarefied air, with the indications for the employment of these agents.

First, as to *the absolute method*, the method of Tabarie. In this, it is to be remembered, there is a complete change of pressure, the patient respiring air of the same density as that in which he is immersed. The effects of the *compressed air-bath* are due both to the physical changes produced in the air itself by the degree of condensation employed (from one-fifth to three-sevenths of an atmosphere excess pressure, with gradual transitions), and to the increased pressure exercised both upon the interior of the thorax and upon the periphery.

Inspiration becomes easier, expiration being slower and more laborious. As a consequence, the respirations are reduced in frequency and increased in depth, and the mobility of the thorax is increased. These effects continuing after a return to ordinary conditions, the ultimate effect is a gain in vital capacity.

The dilatation of the heart is antagonized,

but to a less degree than its contractions are aided ; for the normal amount of inspiratory negative differentiation can be brought about by increased muscular effort. Arterial blood-pressure is, upon the whole, lowered, so that the pulse becomes smaller and slower ; and the blood tends from the superficies, both respiratory and general, to the deeper parts, and to those vessels contained in cavities with rigid and firm walls. There is increased absorption of oxygen and increased tissue-change, therefore increased nutrition and increased excretion. Upon the nervous system the effects are sedative and soporific. Concerning pathological conditions, both pulmonary and cutaneous, it may be noted that hyperæmia is diminished and absorption of effusions and inflammatory new formations, mechanically favored by compression ; exactly as a bandage favors the same results.

The therapeutic indications are found in chronic congestive and inflammatory conditions of the skin, acute and subacute inflammations of the air-passages, chronic bronchitis, pulmonary emphysema unaccompanied by cardiac lesion, bronchial asthma, whooping-cough, pleuritic effusions, and the various forms of pulmonary consumption (in which are included the chronic pneumonias and broncho-pneumonias), unless contraindicated by the danger of absorption of septic products present in lungs or bronchi, by high daily fever, by softening or excavation of lung-tissue sufficient to give rise to danger of rupture or of hemorrhage, or by general tuberculosis. Its especial advantage is to prevent extensive lesion in predisposed subjects with incipient

disease. It has also been found useful in anæmia and chlorosis, and in obesity. Some observers commend it in certain cardiac lesions; others prohibit it in all. In the absence of personal experience, I can simply express a theoretical leaning towards the more cautious view. Other contraindications are found in states of the brain, spinal cord, or abdominal viscera, in which an increased supply of blood would be prejudicial.

The action of *rarefied air* in the pneumatic chambers is generally likened to the effects produced by ascent of mountains or in balloons, but certain differences exist owing to variation of atmospheric conditions in the higher regions. The rarefied air-bath has not been extensively employed in therapeusis, and as the recommendations made are largely based upon theoretical considerations only, I shall abstain from repeating them.

The differential method of pneumato-therapy, is that which is most readily available, most manageable, and, on the whole, most beneficial. Of this I can speak with positiveness, the result of some five years' personal observations. It introduces a new element into our physiological observations,—namely, the possibility of facilitating or impeding the performance of both or either of the phases of respiration, together or alternately. It is, then, particularly applicable in the case of patients too weak to respire properly unaided, or in whom pathological conditions oppose one or the other, or both, of the phases of respiration, or in whom the normal respiratory rhythm has become perverted, whether from excess in one direction or from

deficiency in the other. It also produces circulatory effects, due to the difference between intra-thoracic and extra-thoracic pressure,—that is, between the pressure upon the heart, pulmonic vessels, and intra-thoracic systemic veins and arteries on the one hand, and upon the peripheral vessels on the other hand.

Atmospheric pressure upon the surface of the body remaining unchanged, increase of pressure upon the pulmonary surface may be obtained,—1. By inspiration of compressed air. 2. By expiration into compressed air. Decrease of pressure upon the pulmonary surface may be obtained,—1. By inspiration of rarefied air. 2. By expiration into rarefied air.

These procedures may be so combined as to maintain the increase or decrease during both phases of the respiratory act, or to allow of increase during one phase and decrease during the other. All of these combinations were recognized and described by Waldenburg.

Increased pressure facilitates inspiration and impedes expiration. Decreased pressure facilitates expiration and impedes inspiration.

The facilitation of inspiration or of expiration, or of both, is usually the object of treatment; hence *inspiration of compressed air, expiration into rarefied air*, and the combination of these procedures, are the methods most widely employed. Inspiration of compressed air with expiration into the same medium, which, as pointed out by Dr. Platt, is virtually the method of the pneumatic cabinet, is highly recommended by recent American observers. The effects of these various procedures will vary,—1. With the degree of

pressure employed. 2. With the time during which the process is continued; and, therefore, at different periods during its progress. 3. With the amount of voluntary co-operation on the part of the patient. The rationale of these variations being readily understood, and their effect easily deducible from the physiological studies already made, it will only be necessary to give what may be called an average summary under each head. It may first be stated in a general way that the amount of excess or diminished pressure is small,—from one-eightieth to one-thirtieth of an atmosphere; much less then, than in the absolute method. The time varies from ten minutes to half an hour or longer, with interruptions. A period of absolute rest should precede, and another follow, each period of treatment.

Inspiration of Compressed Air.—The excess pressure employed varies from one-eightieth to one-thirtieth of an atmosphere (+ 9.5 to + 25 mm. Hg.). From fifteen to thirty respirations may be made continuously, and the process repeated after a rest of five or ten minutes. The patient, if able, should stand, and, when necessary, the physician may aid inspiration by pressing the shoulders backward, or assist expiration by compressing the chest. When it is desired to localize or locally increase the effect, the healthy side of the chest (*e. g.*) may be strapped, or its motion diminished by manual pressure or pressure against a wall, chair-back, or other suitable object.

The effects, which follow from considerations already detailed, are decrease of muscu-

lar exertion necessary for inspiration, dilatation of the alveoli beyond that attainable by voluntary effort; increase in the quantity and in the penetrating power of inspired air,—therefore reopening of air-cells disused from weakness, occluded by the products of secretion and desquamation, or agglutinated from similar causes, and increase in the volume and weight per volume of O brought to and absorbed by the blood; a greater area of blood surface being reached. The subsequent expiration is sometimes slightly retarded, but is deeper, the quantity of air exhaled and of CO_2 eliminated, being increased. Tidal and complemental air are thus increased, reserve air diminished; the first two quantities and a portion of the third quantity, being added to form what is now virtually an increased volume of tidal air, reaching two hundred cubic inches or even more. Diminished frequency of respiration, increased expansion, ventilation, and gaseous exchange, are therefore the immediate effects; increased vital capacity the ultimate and permanent result. The circulatory effects are those of heightened pressure,—namely, an augmented centrifugal tendency of the blood-current; increased force of the ventricular systole; quickening of the pulmonic circulation, bringing more blood, therefore more corpuscles, more hæmoglobin, in proportion to area, into contact with the increased quantity of O; filling of the systemic vessels, with rise of arterial blood-pressure; the pulse becoming at first more rapid, afterwards slower, full, and hard. The blood circulates more actively throughout the body, being richer not only in oxygen, but also in

nutritive materials, for pressure upon the diaphragm, transmitted to the abdominal viscera, stimulates absorption of chyme; while heightened pressure and augmented volume of blood in the viscera tend to stimulate functional activity. Thus, increased oxidation and tissue-change stimulate appetite and improve nutrition. Passing to effects upon pathological states,—pulmonary hyperæmia is relieved; inflammatory products are absorbed; cough and expectoration are at first increased, from dislodgment of accumulated materials, afterwards diminished from relief to irritation and diminution of pathological secretions. Increased ingestion and assimilation repair pathological waste, and the increase in weight sometimes exceeds the previous record in good health. Sleep is promoted; night-sweating is often arrested; hæmoptysis is sometimes checked.

Expiration into compressed air impedes the act and requires greater muscular exertion. If this be sufficient to overcome the obstruction, the amount of air expelled is increased; otherwise it becomes gradually diminished, and the subsequent inspirations are therefore rendered shallower. In other words, tidal air is at first increased, but soon diminished; residual air gradually encroaches upon reserve air, tidal air, and finally upon complemental air; the entire volume becoming practically stationary or residual. The excursions of the diaphragm and thoracic walls become less and less, but at the expense of the contraction, fixed expansion being finally maintained; and if the procedure be pushed to excess with too high a pressure, apnœa may result. Pulmo-

nary ventilation is diminished, and gaseous exchange is retarded; the absorption of O by the hæmoglobin being, however, facilitated, although the excretion of CO_2 is diminished. The effect upon the circulation, is an exaggeration of that produced by inspiration of compressed air, being practically the same as in Valsalva's experiment—depletion of the lungs and heart; over-distention of the systemic vessels, especially the veins. The pulse may disappear from compression of the subclavian artery. Upon pathological conditions, the pressure effects are similar to those already detailed.

Continuous respiration of compressed air, therefore, greatly augments the distention of the thorax and of the lungs, maintaining the patency of the alveoli; and while it diminishes during treatment the volume of air exhaled, the result may nevertheless be properly stated as an increase in vital capacity. The ventilation of the lungs is diminished, but, on the whole, gaseous exchange appears to be slightly increased. There is constantly increasing interference with the dilatation of the heart, and an outward pressure replaces the normal thoracic aspiration of the blood, thus blocking the systemic veins, while at the same time the arteries are distended. Arterial tension, increased at first, soon falls, and the pulse becomes small, slow, and feeble.

Inspiration of rarefied air, which should be conducted against a very small negative pressure, rarely exceeding one-sixtieth of an atmosphere, increases the muscular effort necessary to produce expansion of the chest, and the volume of air needed to supply the proper

weight of O. If the requisite effort can be made, there is increase in the elastic tension of the lungs and in the volume of tidal air. If it cannot be made, there is decrease in both these factors. The subsequent contraction of the chest is at first passively facilitated, afterwards impeded from the resistance of the denser outer air. The muscular effort of this phase is thus also increased, and the frequency of respiration, at first heightened by the excitement of impediment, is finally diminished. Ventilation and gaseous exchange are, on the whole, increased, vital capacity augmented, and the muscles of inspiration strengthened. The blood tends at first to leave the periphery and accumulate within the thorax; but, as there is more blood delivered to the left ventricle, and this can contract with sufficient force to overcome the higher peripheral pressure, the final result is a quickening of the circulation with an increase in the fulness, blood-pressure, and tension of the arteries.

Expiration into rarefied air, conducted with a negative pressure of from one-sixtieth to one-twenty-fourth of an atmosphere, facilitates the contraction of the thorax, exerting a moderate suction-force, and greatly increasing the amount of air expelled from the lungs; thus facilitating the collapse of distended air-vesicles. Subsequent inspirations are rendered easier and deeper; more O-bearing air enters the vesicles; ventilation and gaseous exchange are enormously increased; and the increase in vital capacity is very great. The circulatory effects are similar to those produced by inspiration of rarefied air, but more marked. They vary in different indi-

viduals, are evidently different in man and animals, and can be influenced by the manner of subsequent inspiration. While there are conflicting observations as to systemic blood-pressure, there is agreement as to the tendency to pulmonary congestion and the facilitation of cardiac diastole.

The effect of *inspiration of compressed air, with expiration into rarefied air*, is to increase the efficiency of both processes. The alternate expansion and contraction of the lung-tissue stimulates its elasticity. Pulmonary ventilation, both as to interchange of gases and expulsion of effete materials, is vastly augmented. The alternations of opposing circulatory effects relieve hyperæmia wherever present, increase the activity and penetrating power of the blood-current, and stimulate tissue-change and nutrition.

Inspiration of rarefied air, with expiration into compressed air, increases the muscular effort necessary to complete each act, prolongs the respirations, and retards expiration particularly. The alternating centripetal and centrifugal impetus increases the activity of circulation.

Inspiration of rarefied air, with expiration into the same medium (continuous respiration of rarefied air), increases the muscular effort of inspiration, but hastens and facilitates expiration. The centripetal tendency of the blood is maintained during the entire act, and the heart's action is greatly diminished in force and increased in frequency, the general arterial pressure being much lowered.

THE THERAPY closely follows the physiological indications. The degree of usefulness of

pneumatic expedients in any given instance will of course vary with the conditions of the case: and proper hygienic, dietetic, and medicinal measures must also be instituted. In pointing out the classes of cases in which pneumato-therapy is useful, I do not wish to be understood as claiming the method to be competent to cure in every instance.

Inspiration of compressed air, and *expiration into rarefied air*, are the expedients most generally employed, singly or in combination.

Inspiration of compressed air is of benefit in dyspnœa, of almost any origin; in laryngeal and tracheal stenosis; in chronic bronchitis; in chronic broncho-pneumonitis; in chronic broncho-pneumonitis verging on tuberculosis; in chronic desquamative pneumonitis; in chronic interstitial pneumonitis; in atelectasis; in chronic pleurisy with effusion; in the dry pleurisy of early phthisis; in phthisis at any stage short of general softening, with one or more large cavities, but particularly in the early stages, when deficient respiration, impaired circulation, anæmia, and malnutritive dyspepsia in a predisposed subject, suggest tuberculosis even in the absence of pronounced physical signs.*

The good results of this procedure in phthisis result not alone from the primary effects already alluded to,—the opening of dis-

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* It may be remarked here that evidences of pulmonary impairment, indistinguishable by the ordinary methods of physical exploration of the chest, may sometimes be detected during inhalation of compressed air,—a fact first published, so far as I am aware, by Dr. J. Solis-Cohen. *Vide N. Y. Med. Jour.*, October 18, 1884.

used or occluded air-cells, with increased vital capacity, increased pulmonary ventilation, increased activity of circulation, absorption of inflammatory products, relief of congestion,—but also secondarily from the increased appetite; relief of cough, with promotion of sleep; and the general stimulus to local and general nutrition, following the systematic pulmonary gymnastics necessitated. In simple anæmia, or chlorosis, without tubercular tendency, the same good effects may be obtained. In asthma, the inspiration of compressed air is also useful, but high pressures are necessary, and must be cautiously employed. I have succeeded in one case, that of a patient who was attacked in my consulting-room, in cutting short a paroxysm by the employment of a pressure of one-thirtieth of an atmosphere, steadily maintained for nearly fifteen seconds, the expiratory act being held for the time in abeyance. This expedient, which I believe overcomes spasm by a paralyzing effect upon the bronchial muscles, and by inducing fatigue of the diaphragm, was suggested by the experience of Dr. Monell,* who obtained relief in his own person by forced expiration, with his feet braced against the foot-board of his bed, prolonged pause, forced inspiration, pause, and so on. In asthma and emphysema, however, better results are usually obtainable from expiration into rarefied air. In hæmoptysis, good results have been reported from the inspiration of compressed air and its equivalent, —rarefaction of surrounding air in the Brook-

* *N. Y. Med. Record*, August 15, 1866. Cited by J. Solis-Cohen, *op. cit.*

lyn pneumatic cabinet. Some authors, however, have considered a hemorrhagic tendency as a contraindication to the measure. My own experience leads me to the belief that where there is any weakness of the pulmonary vessels, or any peripheral lesion of hemorrhagic tendency, or where it is inadvisable to increase blood-pressure in the brain, or in the kidneys* or other abdominal viscera, the measure is dangerous. In two remarkable instances, elsewhere cited,† I have, however, been forced to credit it with a tendency to the relief of pulmonary hemorrhage; and this seems to be due directly to the relief of the conditions antecedent to hemorrhage,—namely, pulmonary congestion,—with perhaps an exaggerated stasis at one spot, from mechanical obstructions affecting that portion of the circulatory apparatus chiefly. Inspiration of compressed air is also recommended in mitral insufficiency, and in stenosis and insufficiency of the aortic valves. It is theoretically indicated in dilated heart, and with caution in lipocardiac asthma. I have had no experience with it in any cardiac lesion.

Expiration into rarefied air should be combined with the inspirations of compressed air, where it is desired to increase circulatory activity and gaseous exchange, or to get rid of accumulating and decomposing matters in the interior of the respiratory viscus. *Expiration into compressed air* should be combined with the inspirations of compressed air, when it is

* In one of my cases, albuminuria developed during treatment. This may have been merely a coincidence, but at the time I considered it more.

† *Phila. Med. Times*, February 6, 1886, p. 362.

desired to relieve congestion, or to stimulate absorption, or when increase of vital capacity is the principal object. Alternation of the combinations may be necessary in some instances.

Expiration into compressed air is recommended in cases of deficient normal expiration, as a means of strengthening the respiratory muscles.

Expiration into rarefied air is of signal advantage in emphysema, and in asthma dependent upon emphysema. It is of some advantage in spasmodic asthma, of less advantage in bronchitic asthma, though of value in all, and in the latter variety may be usefully combined with inspiration of compressed air. *Inspiration of rarefied air* is at times a better combination in emphysema.

Inspiration of rarefied air may also be employed where it is desired to strengthen the muscles of inspiration by increased voluntary exercise, as in cases of contracted thorax in the earlier stages of phthisis, and in convalescence after pleurisy.

That *forced voluntary respiration*, however useful in suitable cases, cannot replace pneumatic treatment by the differential method in cases where the latter is indicated, is evident from the mere statement that it does not produce differential effects; as well as from the fact that many patients are at first incapable of the necessary muscular exertion. As an adjunct or supplement to the differential treatment, or as a means of keeping up the good effects, it often serves excellently.

Pneumato-therapy, steadily growing in favor as the number of physicians resorting

to it increases, bids fair to assume at last its proper position among the resources of medical art. It can only be damaged, not benefited, by a tendency to indulge in extravagant claims and reckless assertions. There is nothing mysterious about it,—no miracle, no witchcraft. It has its applications and its limitations, and these are exact and capable of determination, almost with mathematical precision. In practice, the benefits to be derived from it will depend upon its artistic employment,—as the result upon a canvas depends not on the chemical nature of the pigments, but upon the skill with which they are laid on.

As with all other therapeutic devices, including the administration of drugs, the more clearly we appreciate the pathological conditions present, and the more comprehensive and accurate our knowledge of the powers and limitations of the agent employed, the more skilfully we can adjust the action of the remedy to the requirements of the disease. The first essential, however, is to get rid of the notion that there is anything mysterious in the process, or that it is not governed by the same unalterable laws that affect all other things under the sun, and from which the sun himself is not exempt,—those laws more inexorable than the laws of the Medes and Persians, in that they were not decreed at the whim of man, and cannot be overturned even by rebels against the Legislator.

OTHER ARTICLES BY THE AUTHOR UPON CONNECTED SUBJECTS:

An Improved Apparatus for Therapeutic Inspiration of Compressed Air. Proceedings of the Philadelphia County Medical Society, 1884, p. 142.

On the Value of a Proper Respiratory Diet in Phthisis. *Medical News*, Philadelphia, August 1, 1885.

Artificial Climatic Effects for "Stay-at-Homes." *Philadelphia Medical Times*, February 6, 1886.

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